Headwaters restoration and recovery in the Wine Country fire zone

Sustainable Water Resources Roundtable

Lisa Micheli, PhD
Pepperwood's Dwight Center for Conservation Science

May 3, 2019

Pepperwood PRESERVE
Inspiring conservation through science

TBC3 Terrestrial Biodiversity Climate Change Collaborative

Pepperwood Mission: advance science-based conservation science across our region and beyond

3200-acre reserve in Mayacamas, partnered with CA Academy of Sciences

The new Dwight Center for Conservation Science

Pepperwood PRESERVE
Inspiring conservation through science

a leader

in advancing the health of Northern California's land, water, and wildlife

advancing science-based conservation throughout our region and beyond

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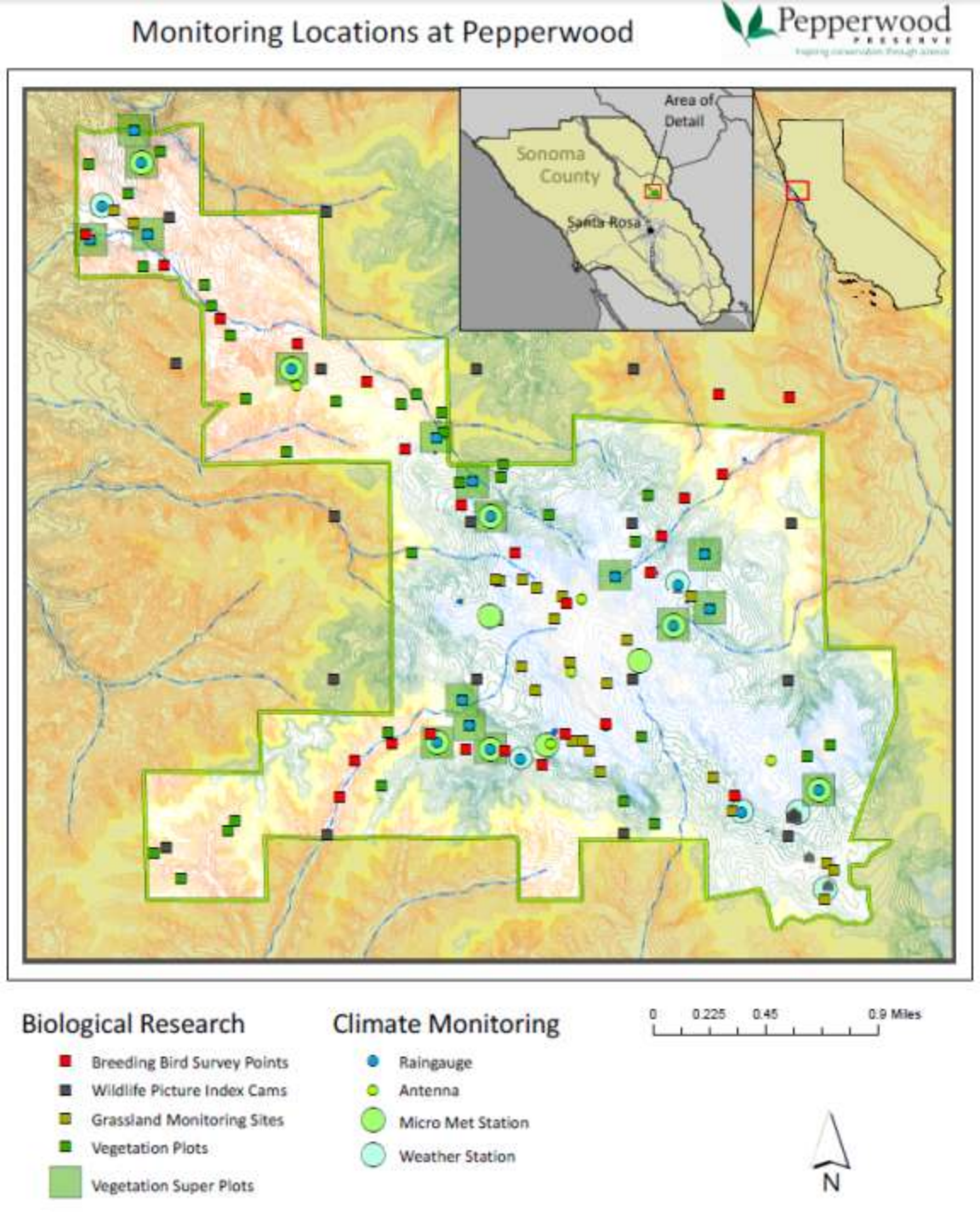

Sentinel Site

Topo-climate-variability of temp, rainfall and humidity across preserve, and interface of coastal-inland meteorology

Full hydrologic cycle monitoring-fog drip, precipitation, soil moisture, stream flow, flow onset

Dominant plant communities-forest and grassland long-term stations and plant phenology transects

Wildlife occupancy-complemented by bird, herpetofauna, invertebrate surveys

TBC3 vulnerability assessments

Water balance

inputs to 3 secondary impact models

direct project outputs

- Snow extent
- Water supply (runoff+recharge)
- In-situ recharge per unit area and per basins
- Water deficits and soil storage

Flint and Flint 2015

River discharge

- Cumulative flow at a gage location (annual values) *Flint 2016*

Vegetation exposure

- Exposure rankings based on BCM and vegetation vulnerabilities

Thorne et al 2016

Fire risk

- % Probability of burn over 30 years

Krawchuk and Moritz 2014

USGS science for a changing world

TBC3 Terrestrial Biodiversity Climate Change Collaborative

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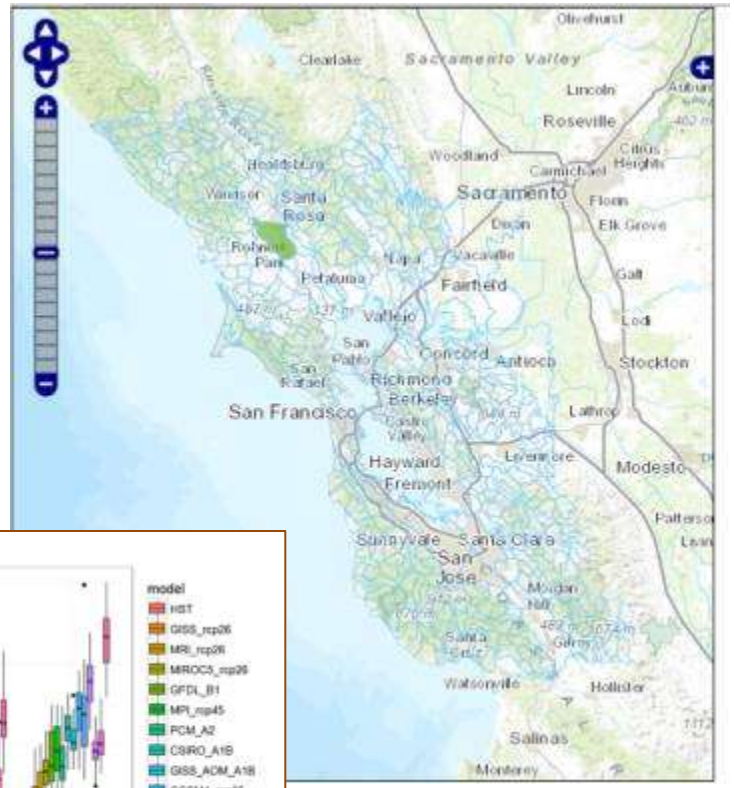
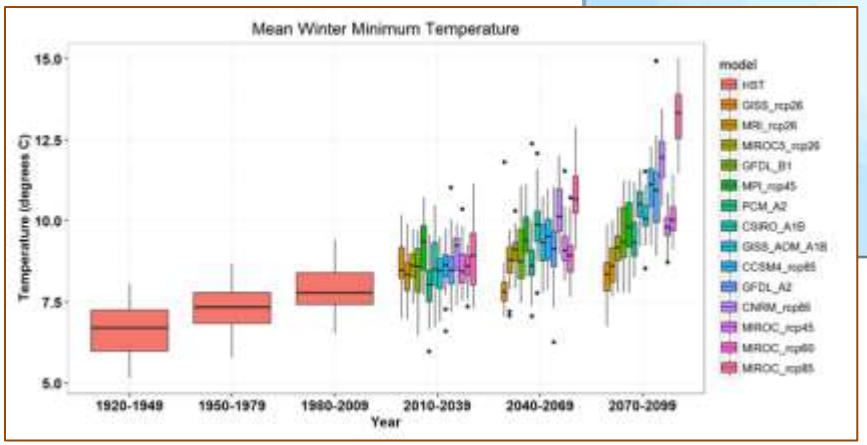
How can I get annual and seasonal time series BCM data for Bay Area watersheds?





BETA now available via the Climate Smart Watershed analyst on California Climate Commons!

calcommons.climate.org/tbc3/ sf-bay-watershed-analyst

TBC3 Terrestrial Biodiversity Climate Change Collaborative

Adaptive Management Planning Goals

- Create a living document to serve as a road map for current and future managers of Pepperwood's land, water, and wildlife (2016)
- Integrate indigenous perspectives into understanding the history of this land and planning for its future
- Demonstrate parcel-scale climate smart management using the Terrestrial Biodiversity and Climate Change Collaborative's (TBC3's) applied climate science tools
- Maintain ecosystem functions and habitat connectivity, while allowing for landscape characteristics and species composition to adjust in response to an increasingly variable climate

PRESERVE-WIDE MANAGEMENT STRATEGY

1. Maintain Hydrologic Connectivity and Promote Drought Resilience

Minimize soil compaction and extent of impervious surfaces

Minimize soil erosion by avoiding concentrating flow around trails or roads and treating eroding roads and trails

Minimize impacts to riparian vegetation

Increase infiltration and soil moisture holding capacity by increasing soil carbon content and porosity through conservation grazing and native grass restoration

Protect springs and perennial water sources

Minimize vehicular soil compaction by prohibiting travel on wet roads or soils

Conserve water from our wells and other infrastructure

Minimize in-stream pollutants including nitrogen, bacteria, excess sediments, water temperature impacts

An unintended result of fire suppression = accumulation of fuel loads

Now thousands (instead of hundreds) of trees per acre : we are actively thinning

What are hydrologic impacts of our forest management?

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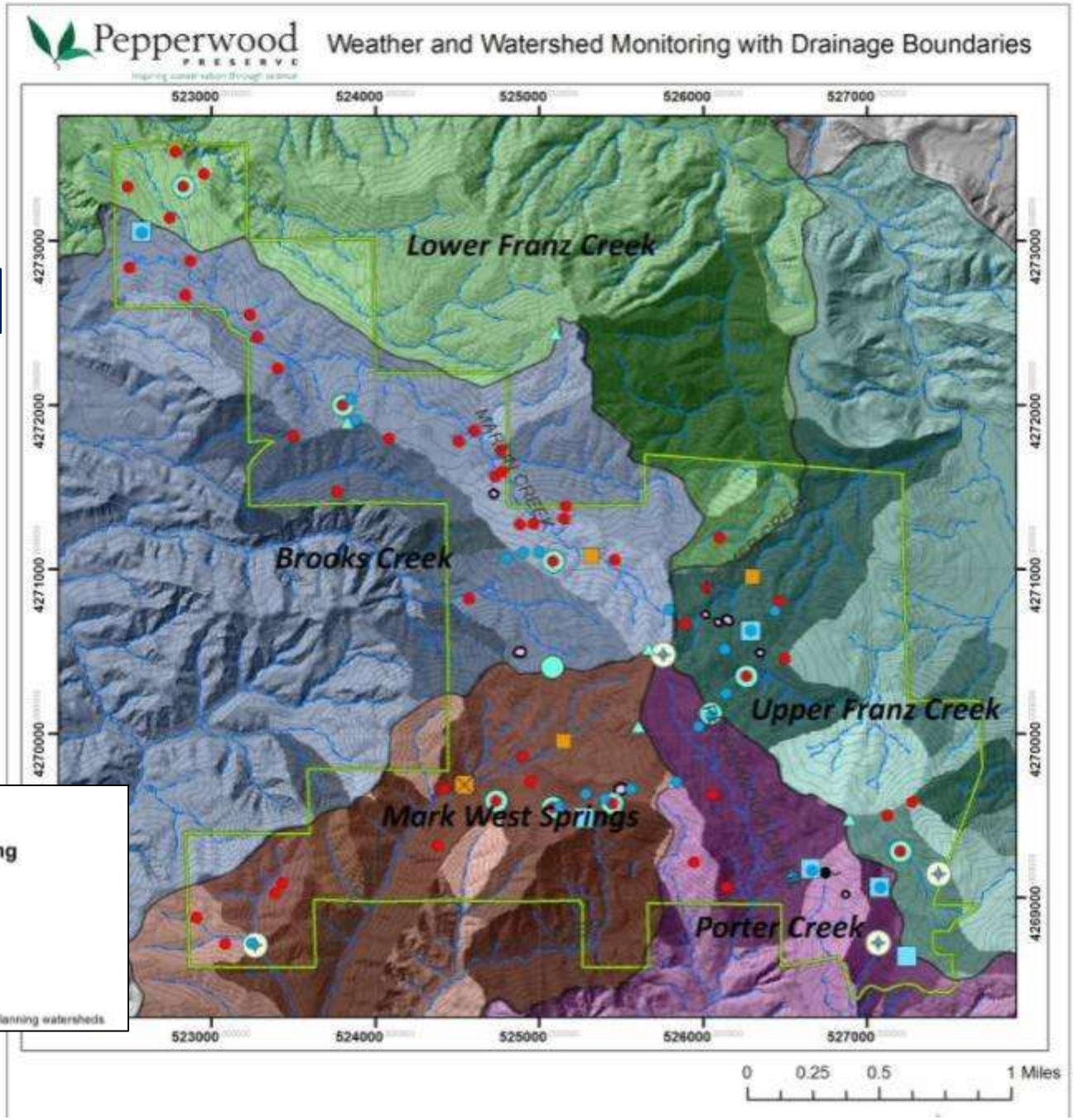
returning disturbance to the landscape

Prescribed burn at
Pepperwood, June 2017

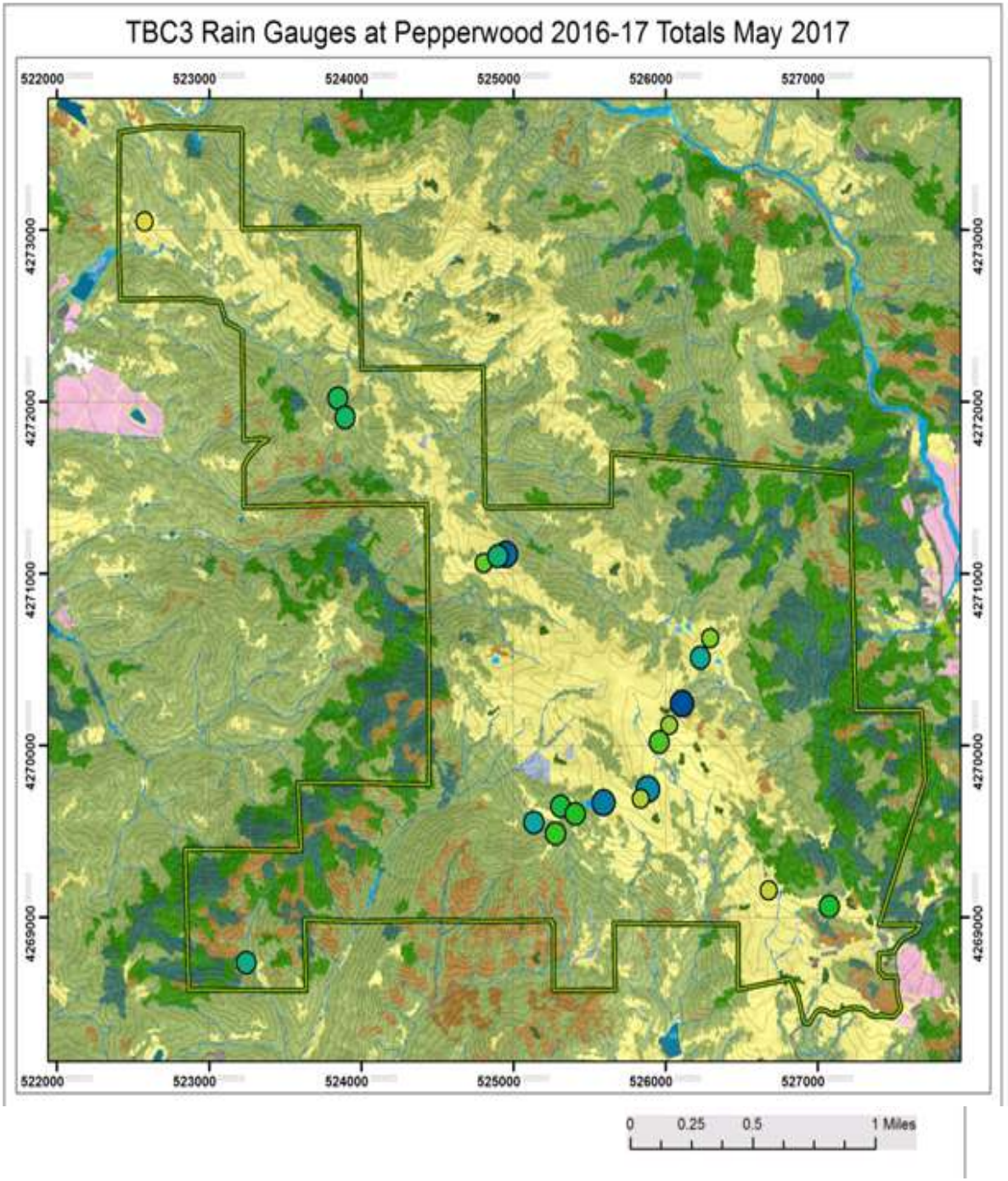
Sentinel site weather and hydrology



Raingauge
iButton Steam Flow Site
Stream Gauging Site
Weather Station
Temp and RH at Veg Plots
Antenna
Micro Met Station
Ground Water Monitoring
Well
Spring
Pond Sites
Streams

Data Sources: Sonoma Veg Map LiDAR hillshade and stream Center Lines, CalWater planning watersheds

Capturing complexity of rainfall distributions

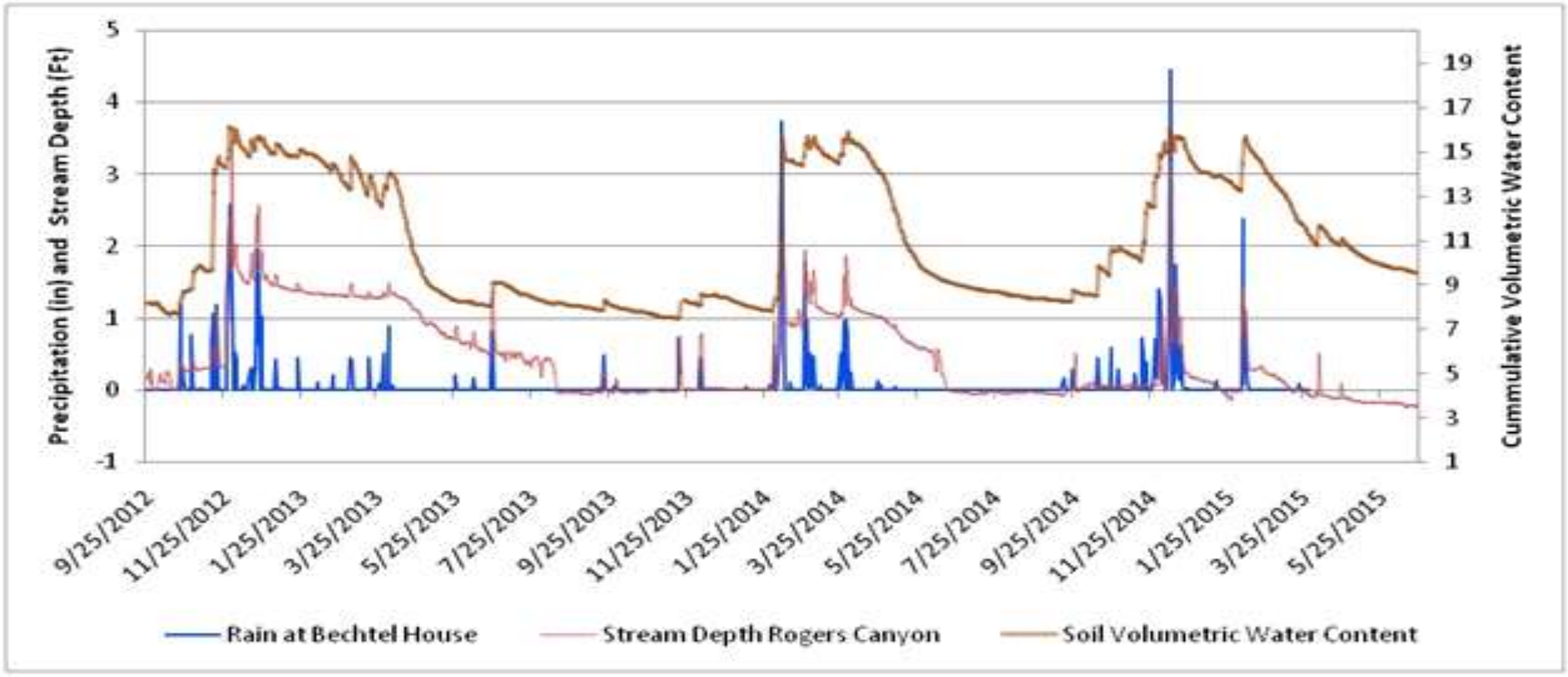


Rain Gauges WY Total (inches, May 2017)

50.956	61.19	67.662
52.146	62.81	68.022
53.737	62.885	69.11
54.485	64.018	71.155
58.63	64.081	71.385
59.261	65.096	71.716
	65.151	73.875
	66.176	

File location: M:\PWD_GIS\MAPS\PWD_RES_PCM_RAN_RainGaugeZoom.mxd

Rainfall, stream depth, and soil moisture



Climatic Water Deficit (mm/yr) Recent, 1981-2010

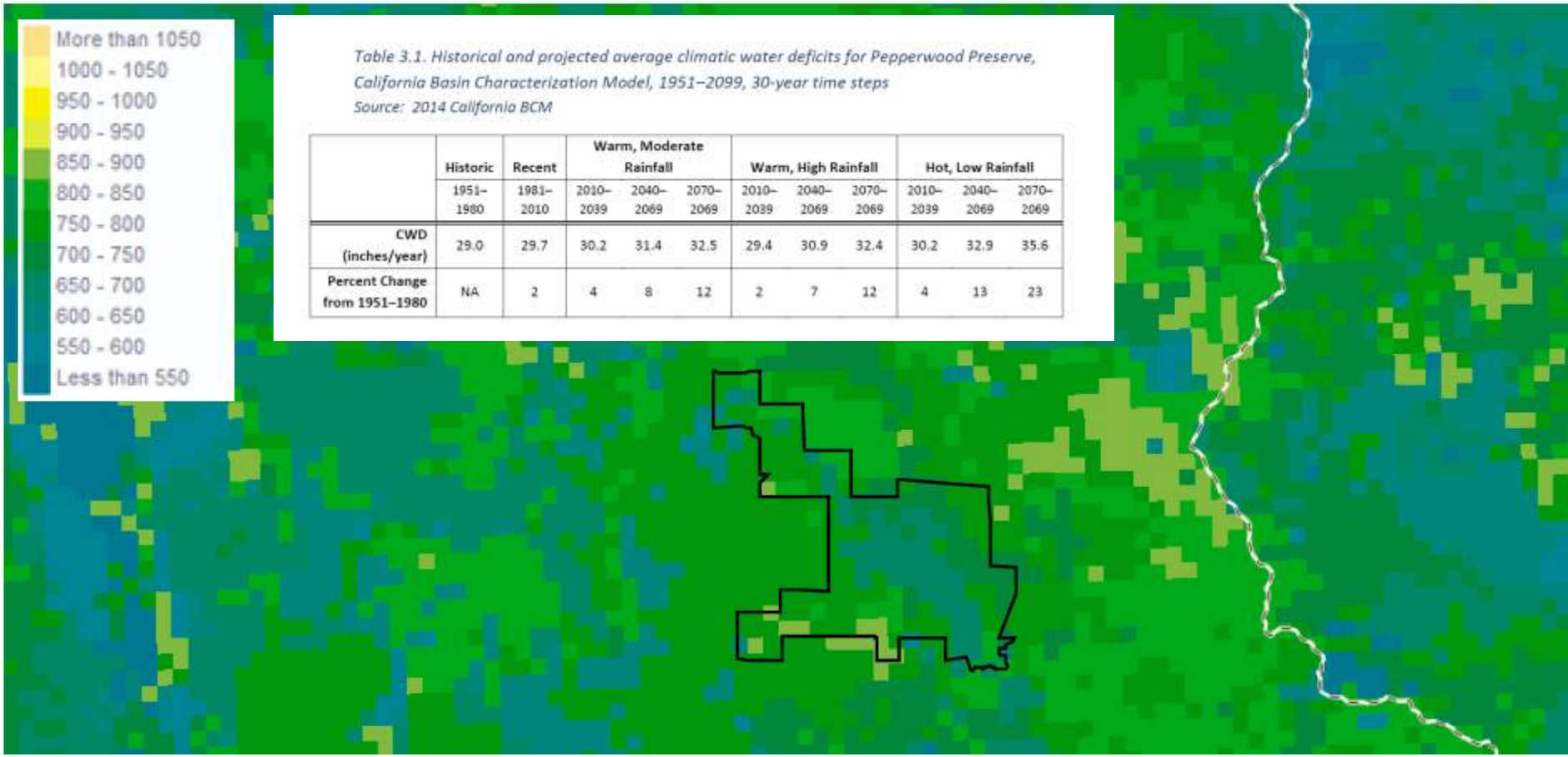


Table 3.1. Historical and projected average climatic water deficits for Pepperwood Preserve, California Basin Characterization Model, 1951–2099, 30-year time steps
Source: 2014 California BCM

	Historic	Recent	Warm, Moderate Rainfall			Warm, High Rainfall			Hot, Low Rainfall		
	1951–1980	1981–2010	2010–2039	2040–2069	2070–2069	2010–2039	2040–2069	2070–2069	2010–2039	2040–2069	2070–2069
CWD (inches/year)	29.0	29.7	30.2	31.4	32.5	29.4	30.9	32.4	30.2	32.9	35.6
Percent Change from 1951–1980	NA	2	4	8	12	2	7	12	4	13	23

BAOSC Explorer tool output: 270 m resolution model

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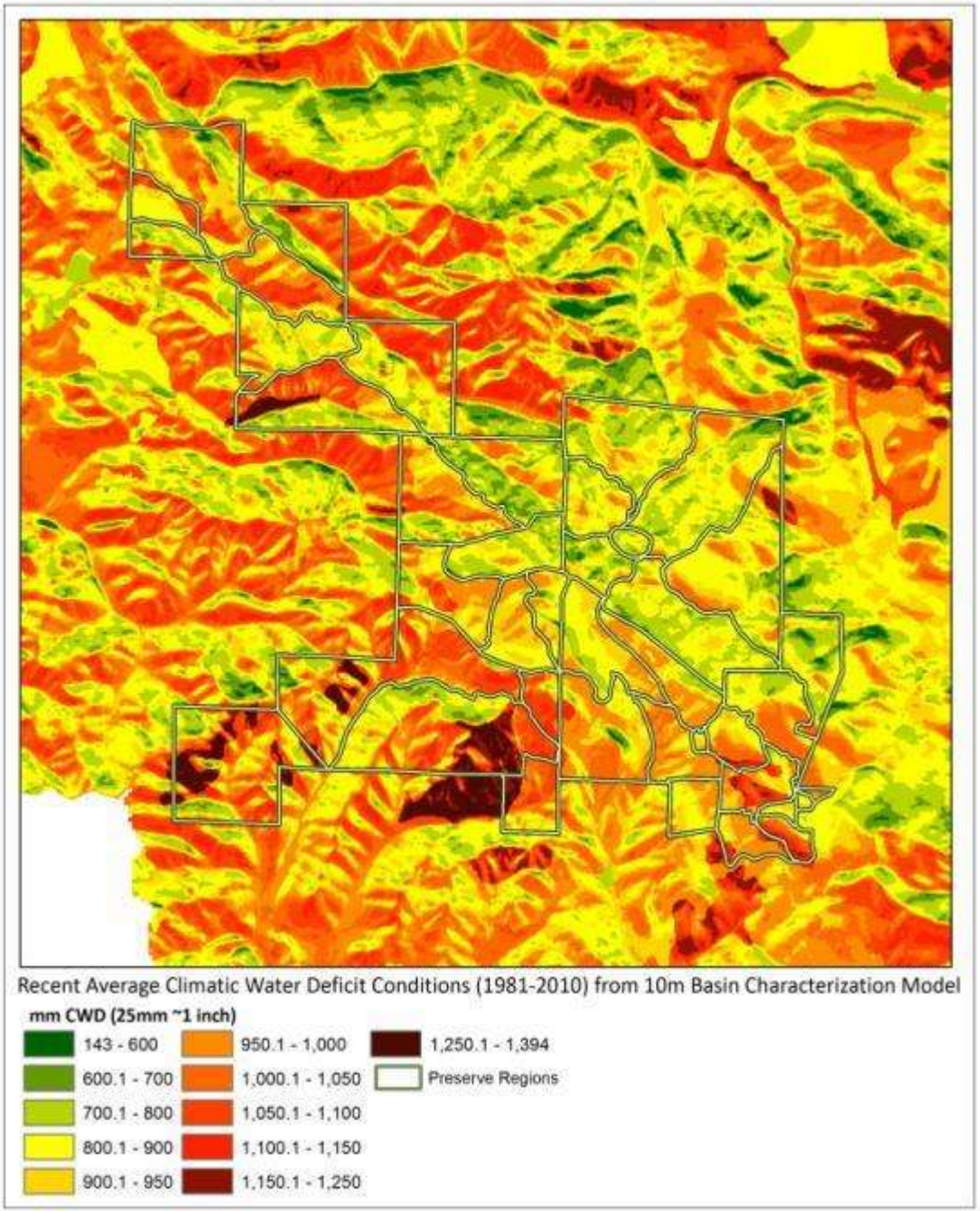
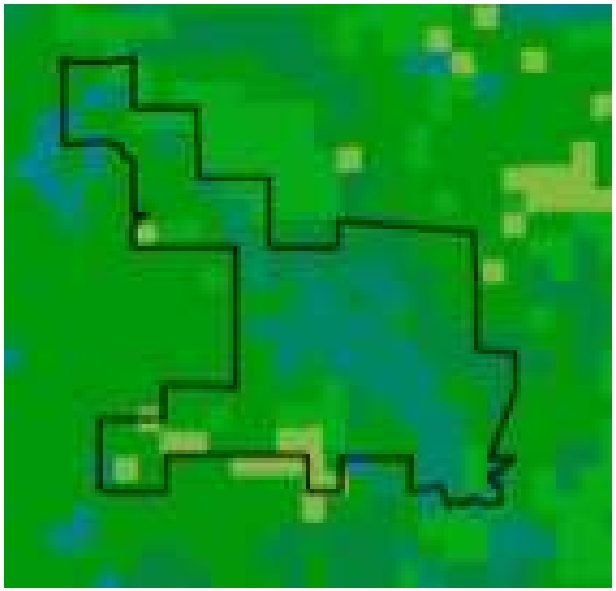
Recent Climatic Water Deficit



Fine-scaled assessments of patterns of increased aridity for ecological applications



270 m for comparison

Knowledge gaps

Pre-fire

- What are the dynamics of groundwater in fractured bedrock systems?
- How variable are Pepperwood's spring flows?
- How significant is fog to the preserve's water balance?
- How are our Conservation Grazing and Forest Management programs impacting hydrology?
- What are the patterns of streamflow in ungauged streams including Martin Creek (Brooks Creek watershed), Franz Creek, and Pepperwood Creek?

Regrouping from a historic event

https://www.livescience.com/60665-california-wildfire-animation-satellite.html

Tubbs Fire unleashed tornadoes

In the late night hours of Oct. 8, the first hours of the Tubbs Fire, a high pressure system over the Central Valley was moving air west in a northeasterly flow to a low pressure system over the coast of California. The change in pressure was so marked that hurricane-force gusts were the result.

Gusting up to 80 mph, the wind funneled into a steep, hilly drainage area along Mark West Springs Road, and was increased in speed by a phenomenon called a Venturi effect.

Pepperwood location

Fire tornado explained

Mini weather system caused by fire.

4 A thermal column is able to reach wind speeds of well over 100 mph, causing damage similar to hurricanes and tornadoes.

2 The heated air rises creating a thermal column.

3 Cooler air gusts into the space left behind the rising air, bringing in oxygen and combustible material.

1 Wind moves horizontally over a fire and the turbulence creates vortices.

Super-heated, the roaring wind entered north Santa Rosa and encountered square-edged buildings and homes that trapped the wind in small spaces, creating swirling vortices from the angular momentum.

WIND

MARK WEST SPRINGS RD.

MARK WEST SPRINGS RD.

Mark West Creek

OLD REDWOOD HWY.

101

HOPPER RD.

FOUNTAINGROVE PKWY.

MENDOCINO AVE.

Coffey Park

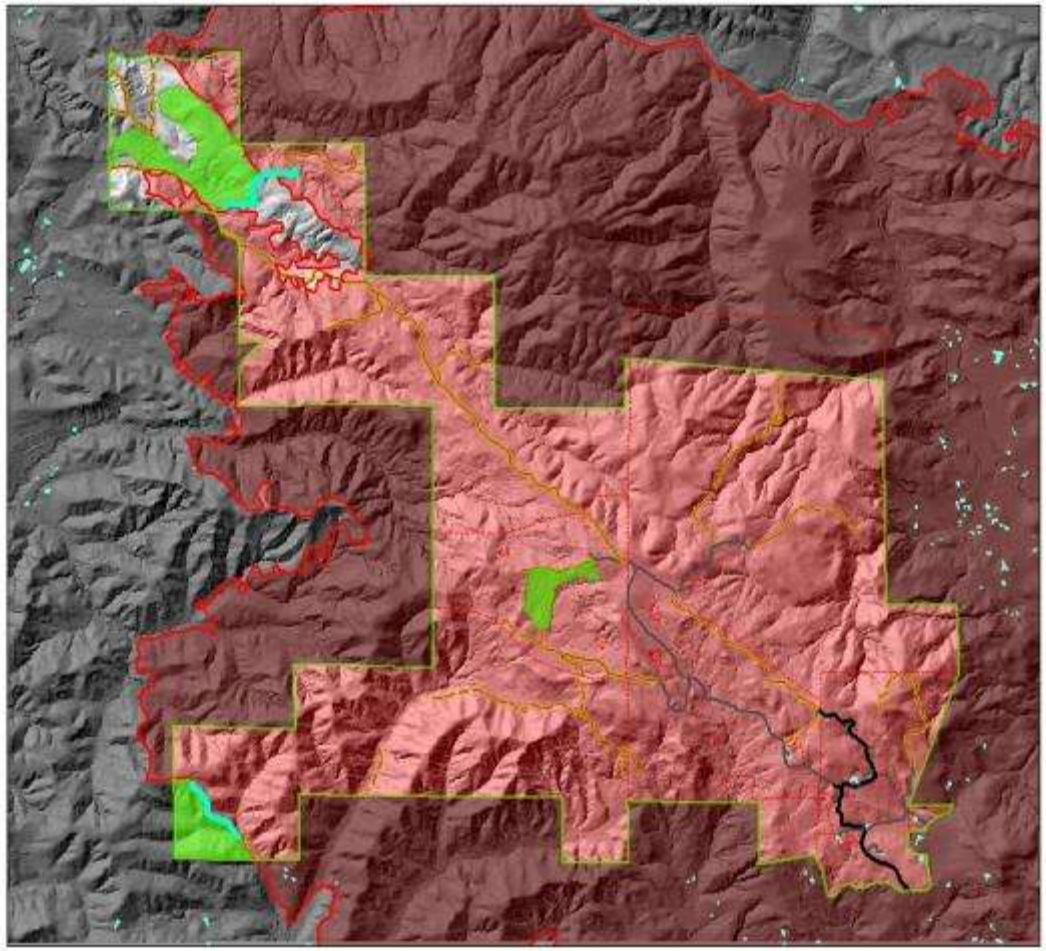
PINER RD.

SANTA ROSA

Sources: Western Regional Climate Center; National Geographic; Howitworksdaily.com

John Blanchard / The Chronicle

Tubbs Fire Official Perimeter, preliminary dozer lines and unburned regions October 2017



0 0.25 0.5 1 Miles

TubbsFireOfficial_171023

TubbsFireOfficial_171023

PWD_BASE_Jursd_Boundaries_PepperwoodPreserve

PWD_BASE_Infstr_Buildings_LiDAR_2013

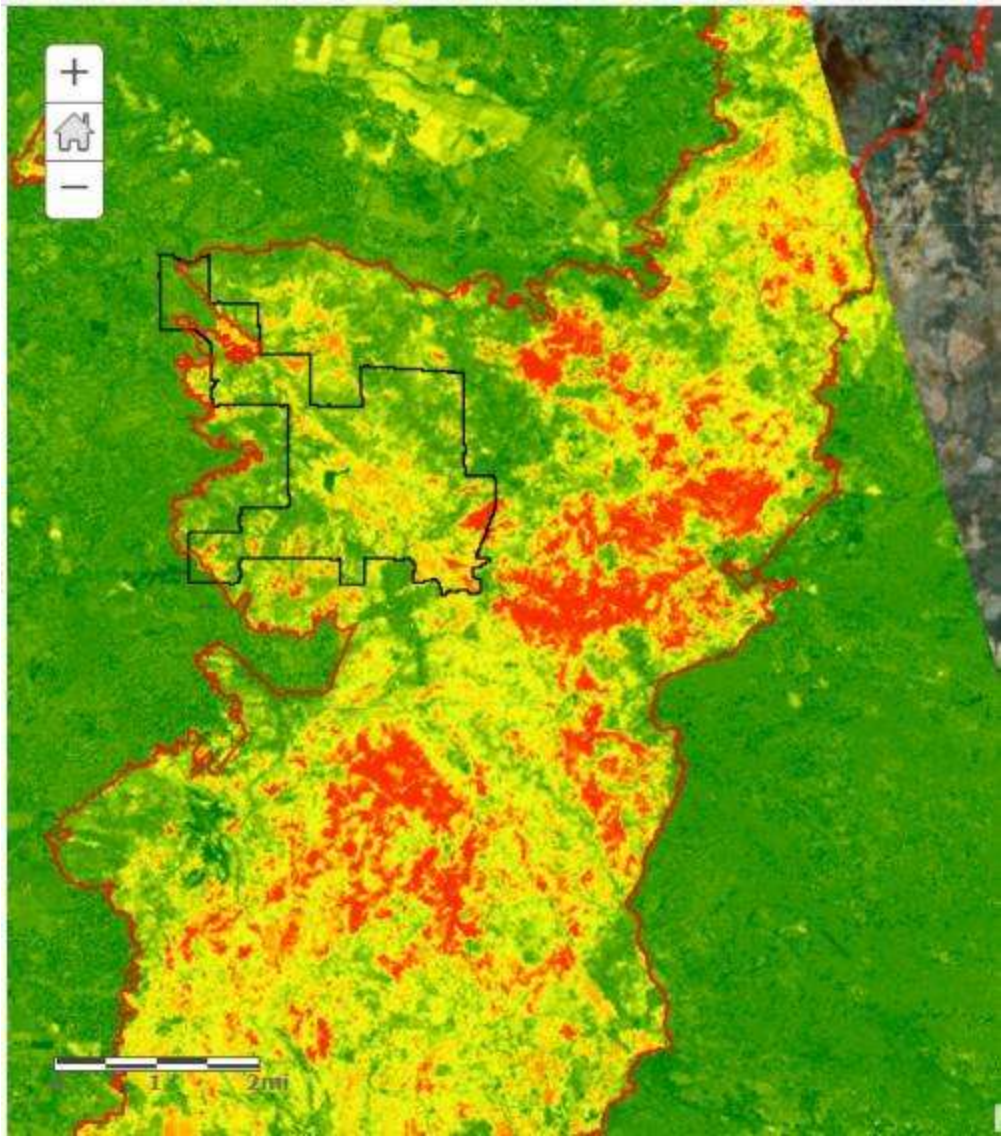
Supression

Observed Dozer Lines

Preliminary Satellite Observations

Unburned regions

Key science questions



Landsat 8 Relativized Burn Ratio (RBR) 20170925 vs. 20171027

LC08_CU_001008_20170925_201701027_RBR.tif

High : 600

Low : -100

Tubbs Fire Perimeter (10/25/17)

TUBBS

Pepperwood_boundary

Preliminary LANDSAT analysis courtesy of Matt Clark, Sonoma State University

What can satellites tell us?

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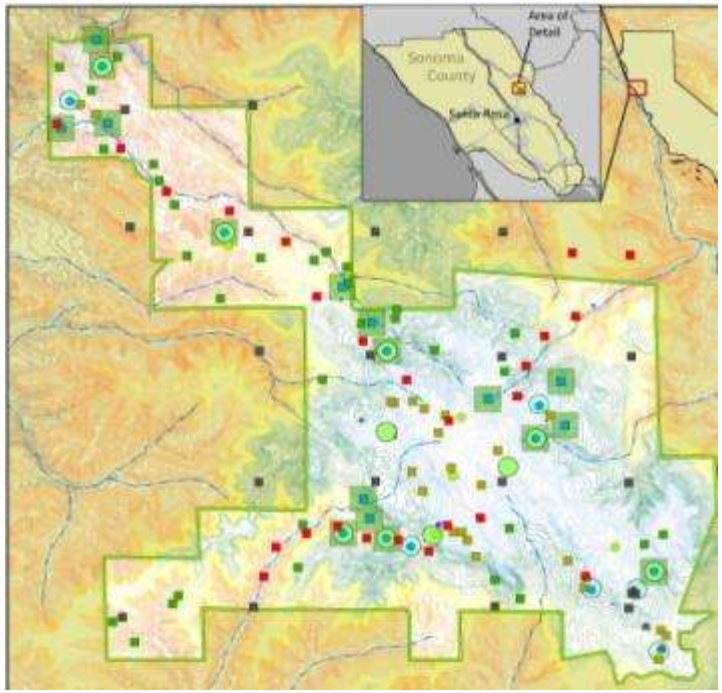
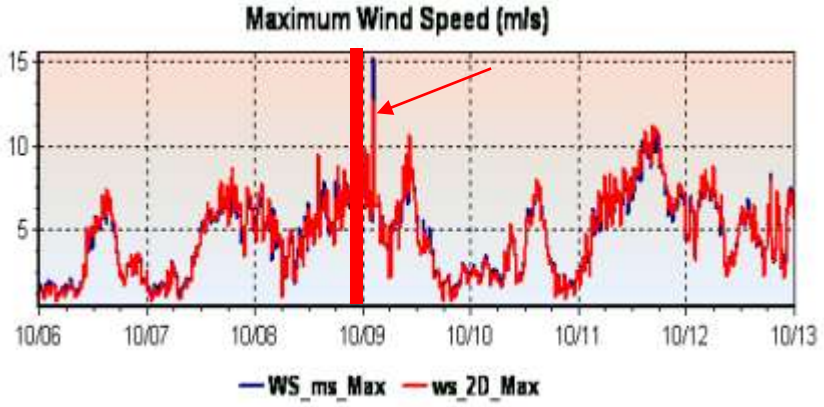
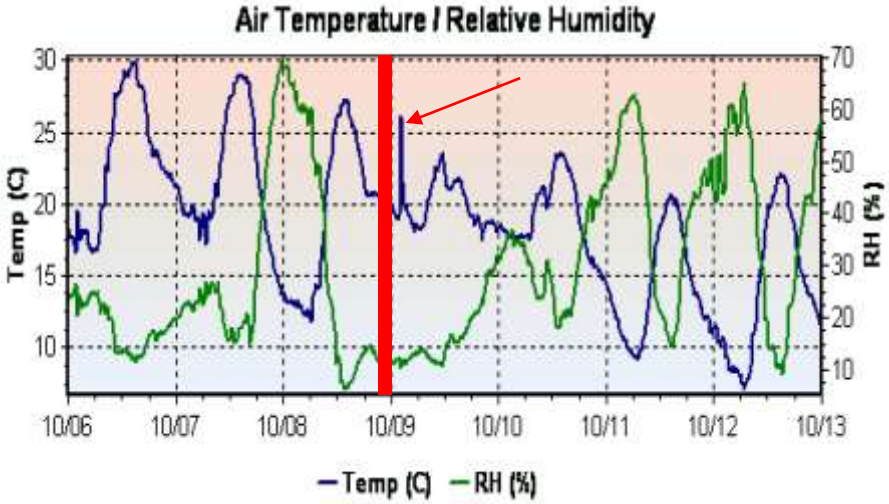
What can our Sentinel Site sensor network tell us?



Our Bechtel weather station survived and has fire event and antecedent data



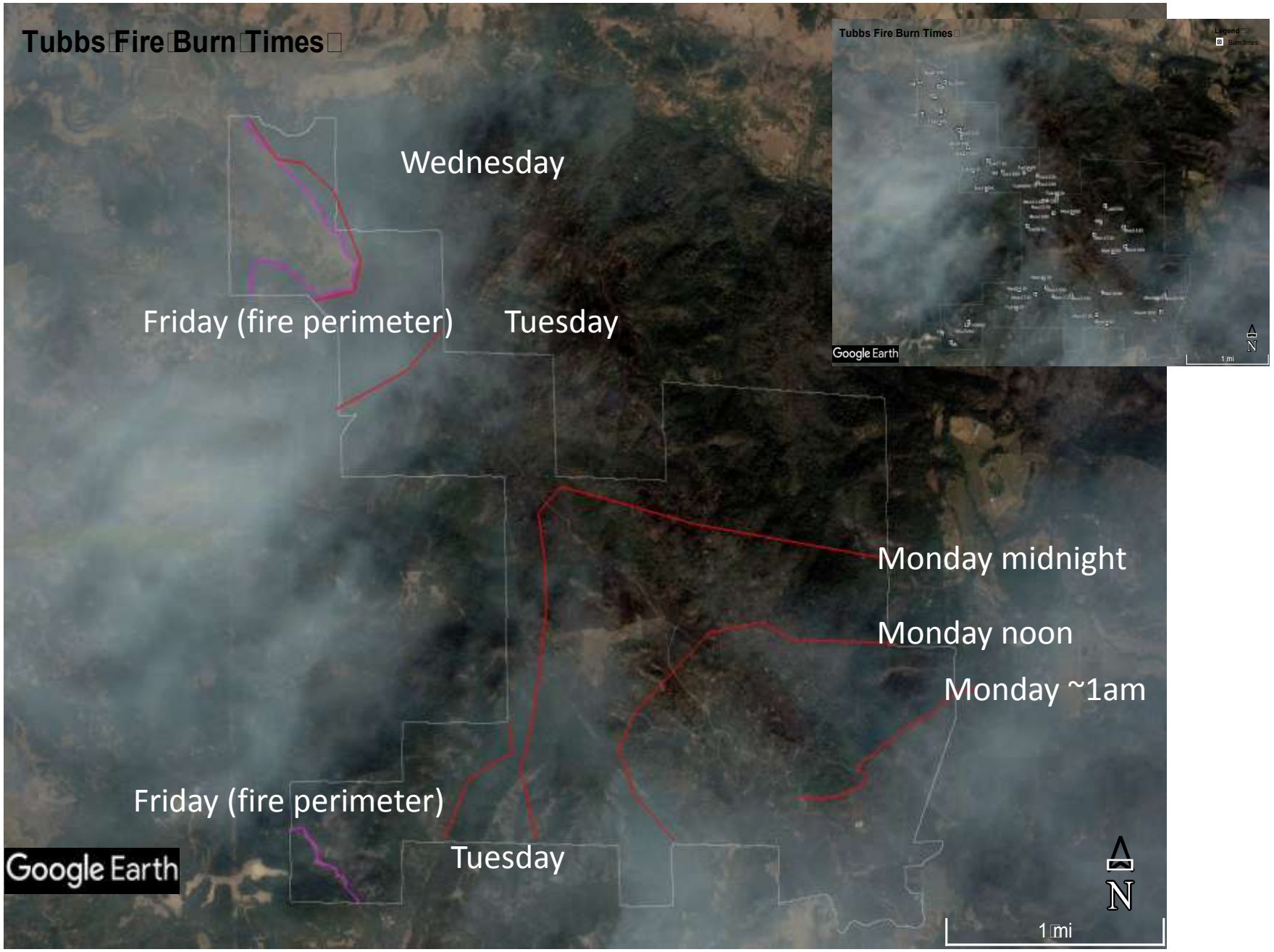


KEY

First 3 hours of Tubbs Fire

Fire effects reach weather station at Bechtel House

*Note the Bechtel House and nearby weather station did not burn.

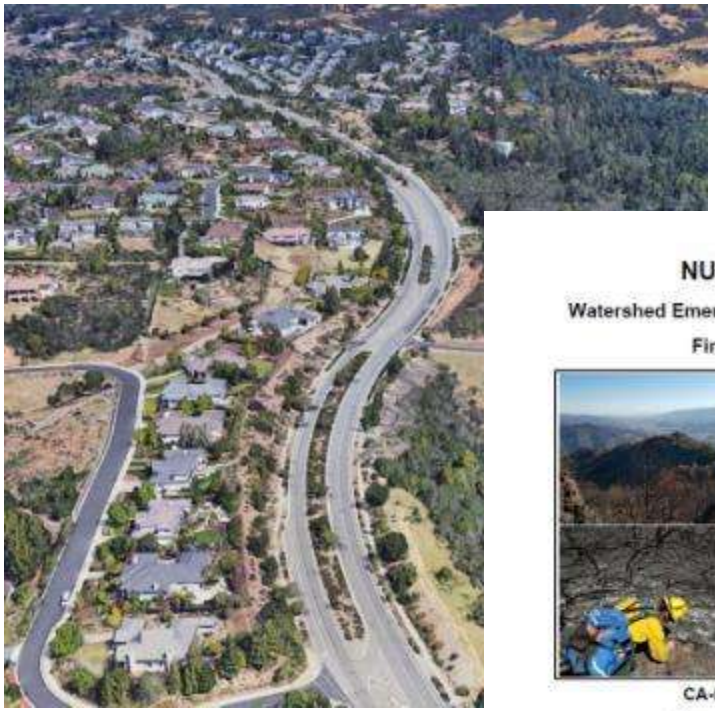

Tubbs Fire Burn Times
Wednesday
Friday (fire perimeter)
Tuesday
Monday midnight
Monday noon
Monday ~1am
Friday (fire perimeter)
Tuesday
Google Earth
N
1 mi
Tubbs Fire Burn Times
Legend
Burn times
Google Earth
N
1 mi

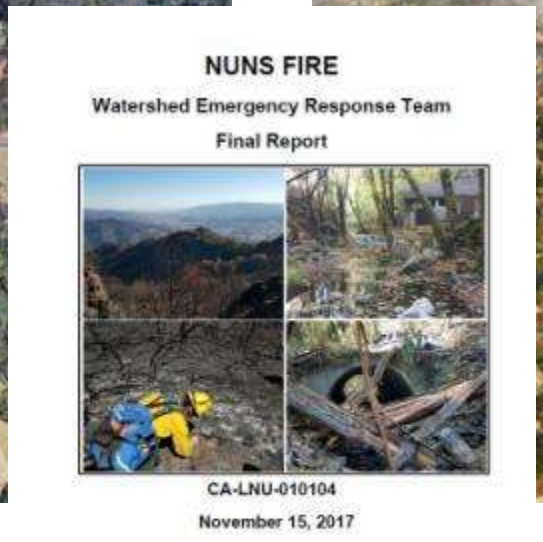
What were the drivers and controls on fire behavior and burn intensity?

Did pre-fire treatments make any difference?

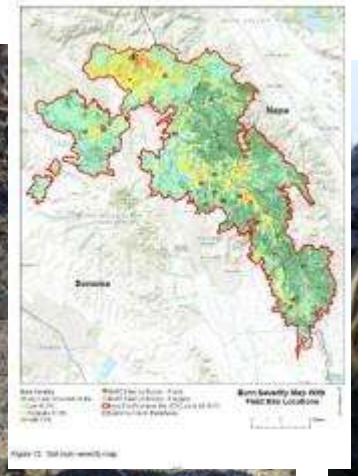
What is meaningful to assess in the field?

How are our watersheds projected to respond in terms of runoff and erosion?

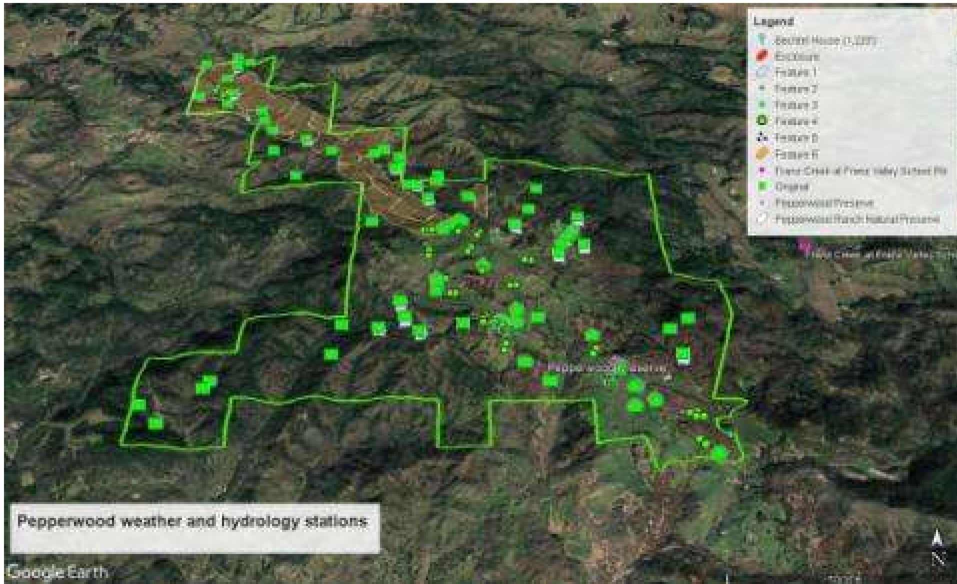




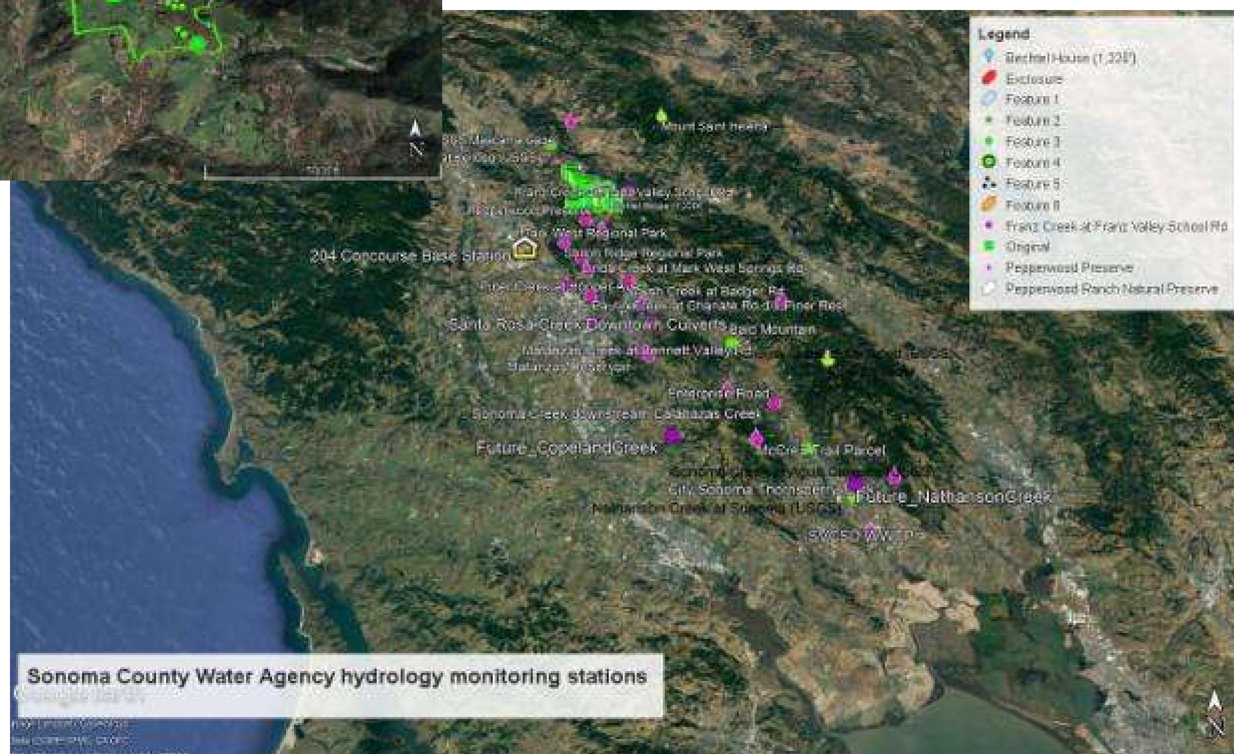
What is meaningful to evaluate in the field to improve our empirical understanding of fire impacts on local watersheds?



Sonoma County Water Agency-USGS-Pepperwood Runoff and Sedimentation project



Rain gages, stream gages, soil moisture probes, sedimentation assessments, complementary flood warning system



SONOMA COUNTY WATER AGENCY

USGS
science for a changing world

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How fire affects soil characteristics: sealing and **hydrophobici**

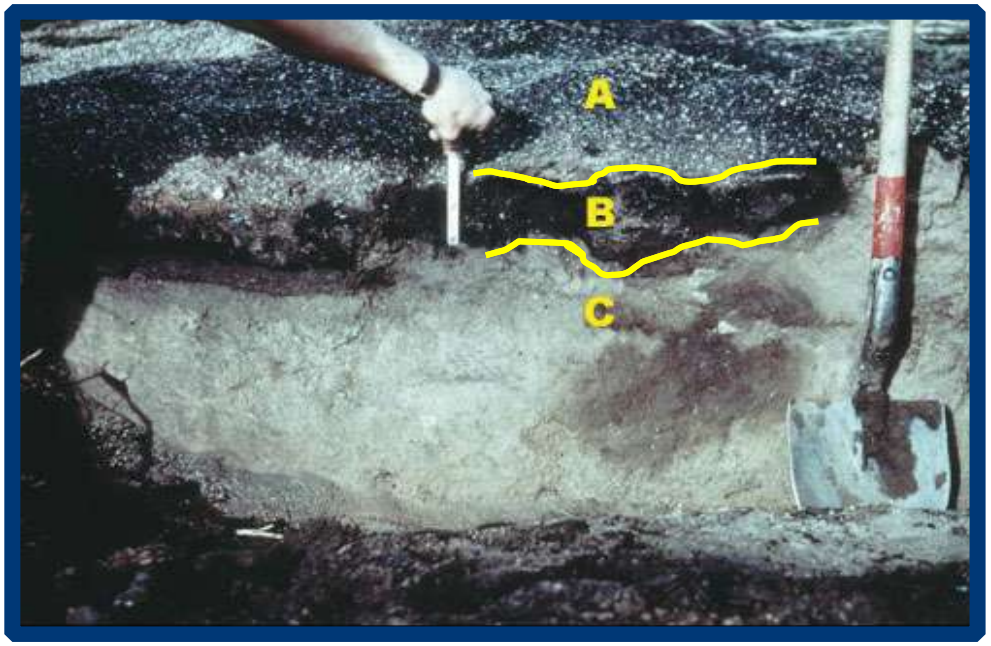
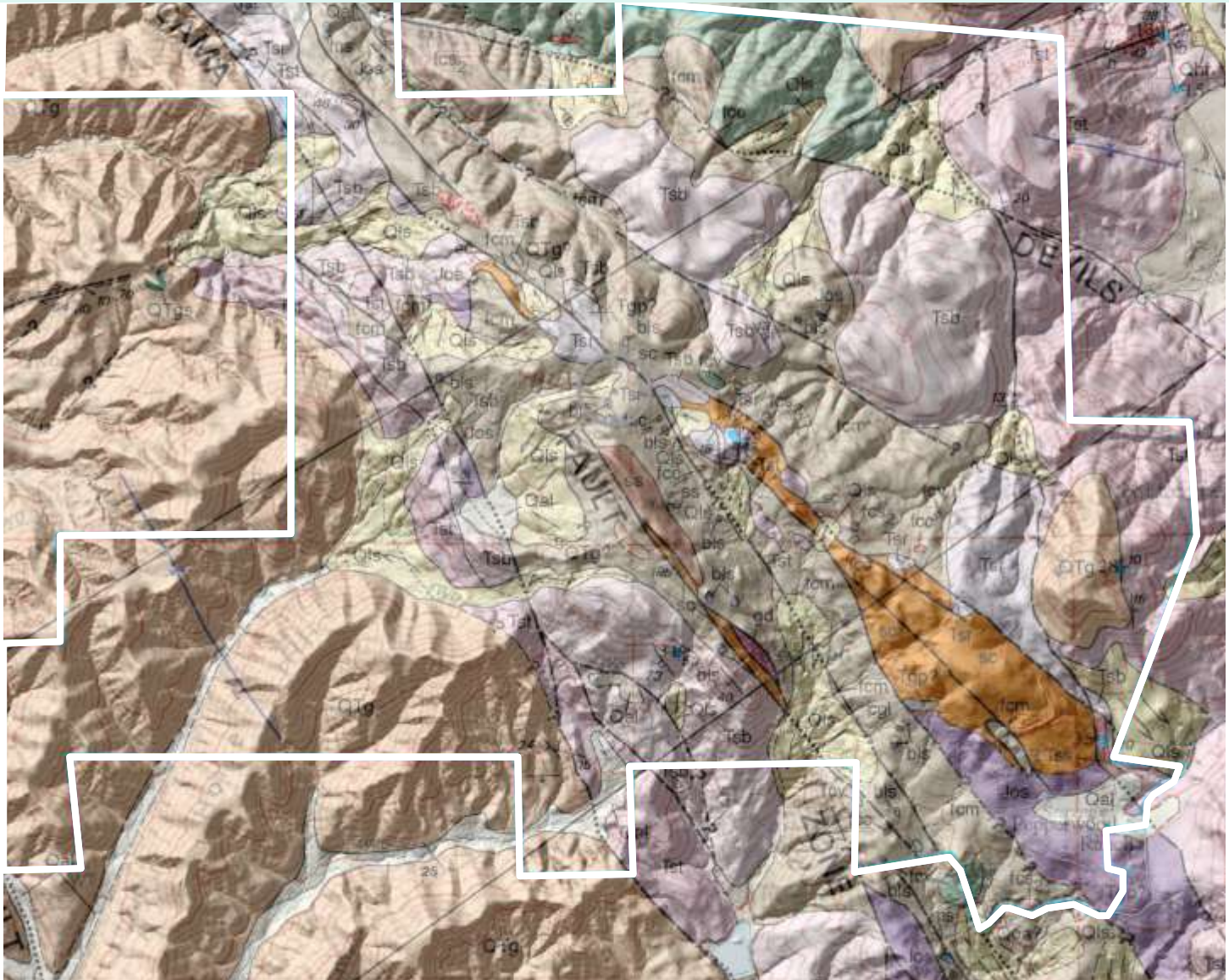
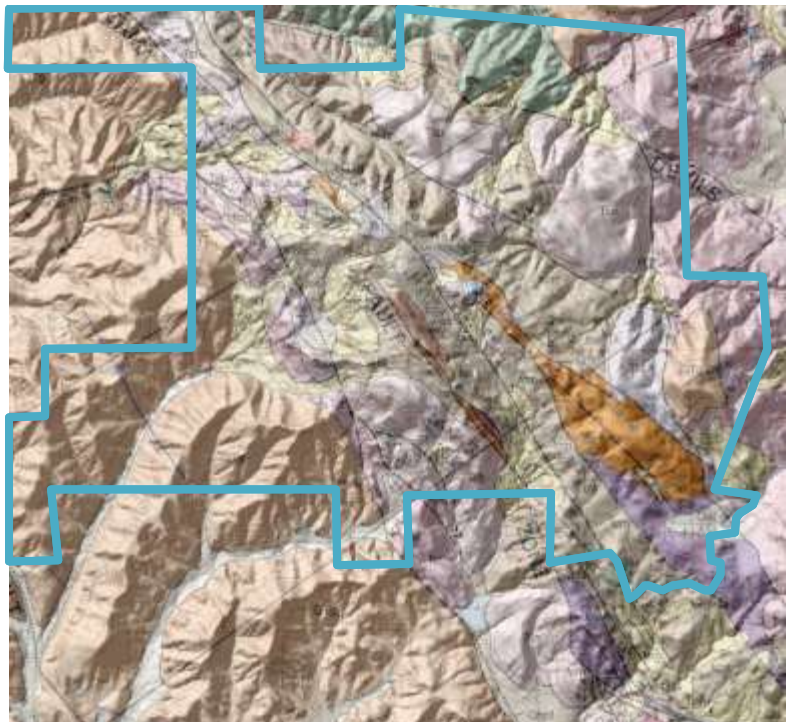


Figure 2.8—The "tin roof" effect on burned chaparral watersheds as described by earlier watershed researchers include (A) the wettable ash and carbon surface layer, (B) the discontinuous water repellent layer, and (C) the wettable subsoil. (After DeBano 1969).

How do Northern CA watersheds respond after wildfires?




Franciscan mélange, deciduous Oak forest
PMD13
3/8/18
WHIRL-PAK
A
B
C



Questions:

1 – How severely did the 2017 Northern CA fires affect soil hydrologic properties?

2 - When do burned watersheds return to their reference runoff conditions? How does this vary with ecologic community/parent material?

3 – What are the rainfall thresholds for processes that transport sediment, and what are the expected hillslope sediment loads to streams?

Objective 1: *Landscape path to recovery*

March 5, 2018

October 2017

What does soil hydrologic recovery look like?

What does soil hydrologic recovery look like?

K_{fs}

Field-saturated hydraulic conductivity

Metric describing ability of water to move through soil

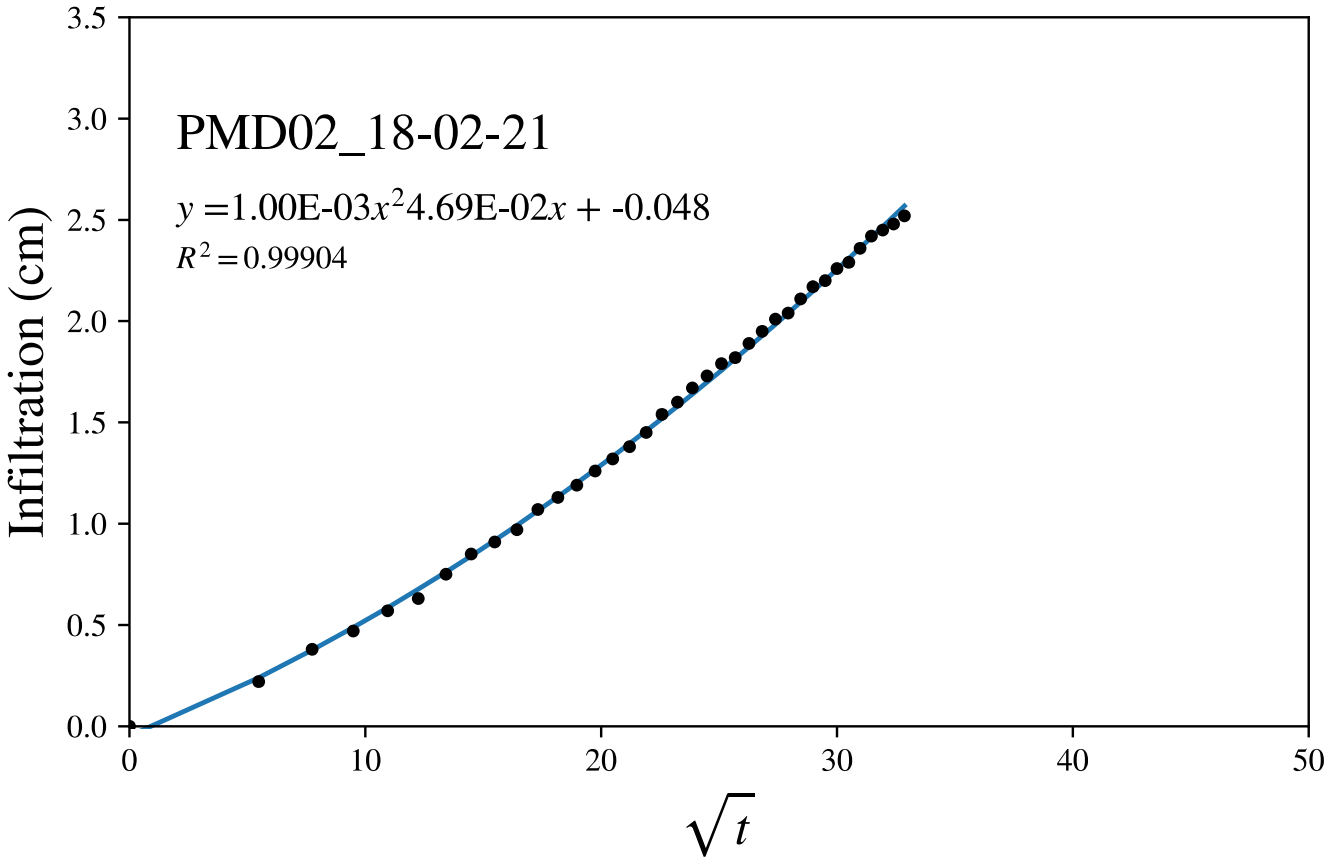
a “lumped” parameter to gauge soil hydrologic change

Incorporates soil structure and texture, water repellency, organic content (Ebel and Martin, 2017)

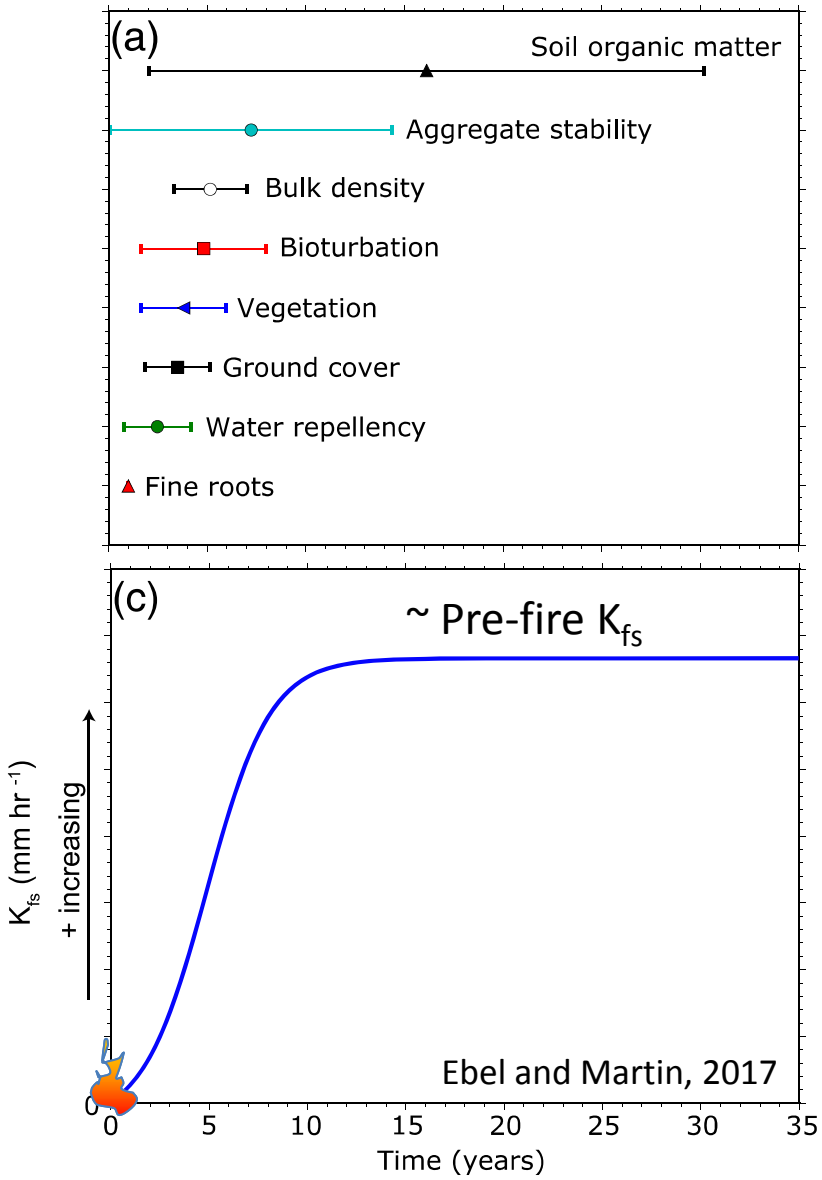
Using infiltration time-series to calculate K_{fs}

$$I = C_1 t + C_2 \sqrt{t}$$

- Slope of line related to K_{fs} (Zhang, 1997)
- Requires independent knowledge of soil grian size distribution



What does soil hydrologic recovery look like?

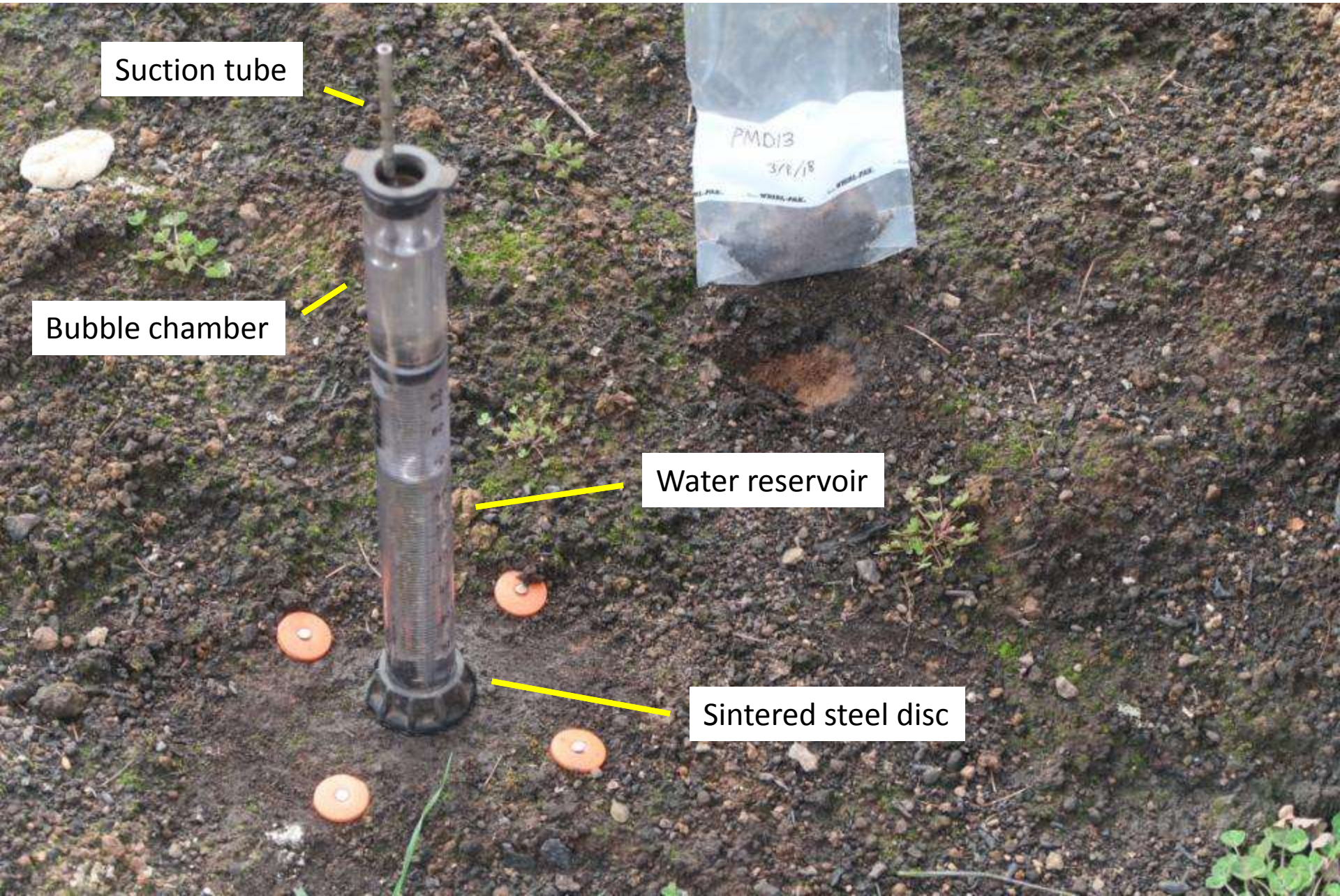


K_{fs} increases depend on a number of processes

Processes covary, but operate over different timescales

Peak changes expected on order of 2-7 years, but unknown for Northern California climatic regimes

Tension-disc infiltrometers



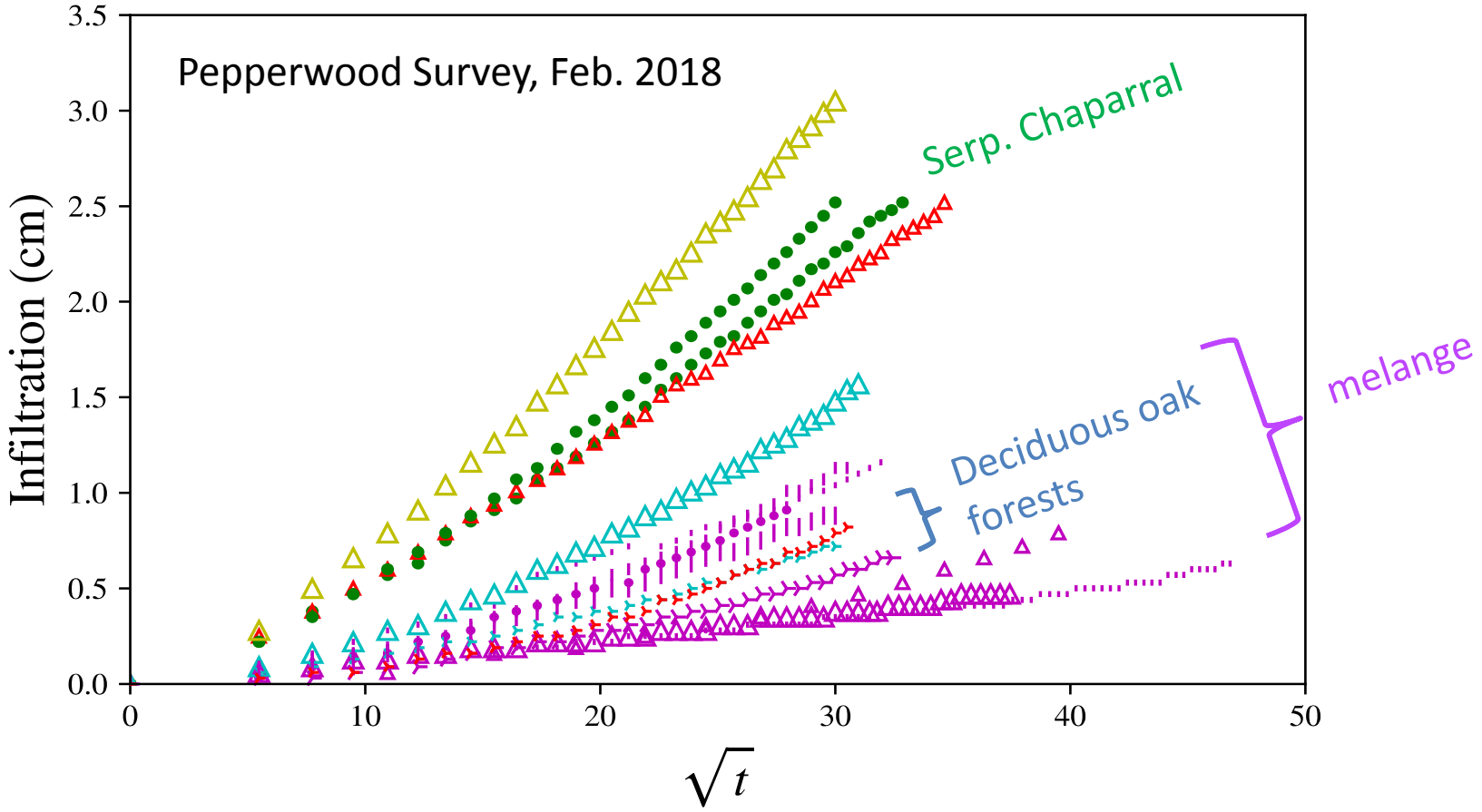

Revisit monitoring sites monthly during wet months, less often during dry months

Constructing a matrix of monitoring sites

	Evergreen	Broadleaf	shrubland/chaparral	herbaceous	*soil burn severity*
Franciscan	PMD06, PMD07, SMD05	PMD12, PMD13	PMD05, SMD04	PMD01, PMD03, SMD03, PMD14	very low
Volcanic	AMD01, AMD03, AMD05, AMD08, AMD09, AMD11, PMD04	AMD06, PMD15	AMD02, AMD04	AMD07,AMD10	low
Sedimentary	AMD16, AMD17, PMD11	AMD18, AMD19, PMD10	AMD12, AMD14	AMD13, AMD15	moderate
Serpentinite	SMD06		PMD02, PMD08, SMD02, SMD07	SMD01	high
Silica Carbonate	PMD09				

40 sites total

~75 including Pepperwood Grassland surveys



Color = geology

Franciscan complex mélange

Serpentinite

Quaternary sediments

Silica carbonate rock

Sonoma Volcanics

Shape = ecology

evergreen forest

broadleaf deciduous

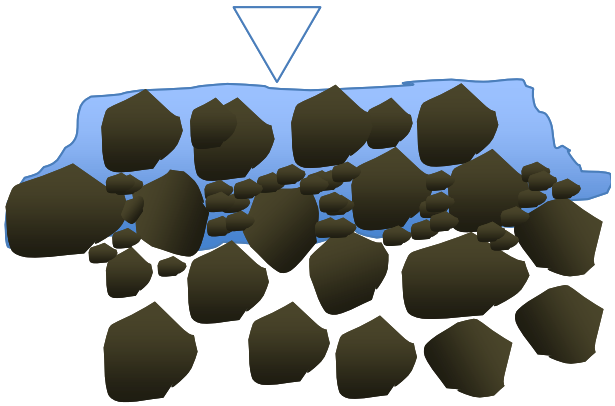
herbaceous

shrubland/chaparral

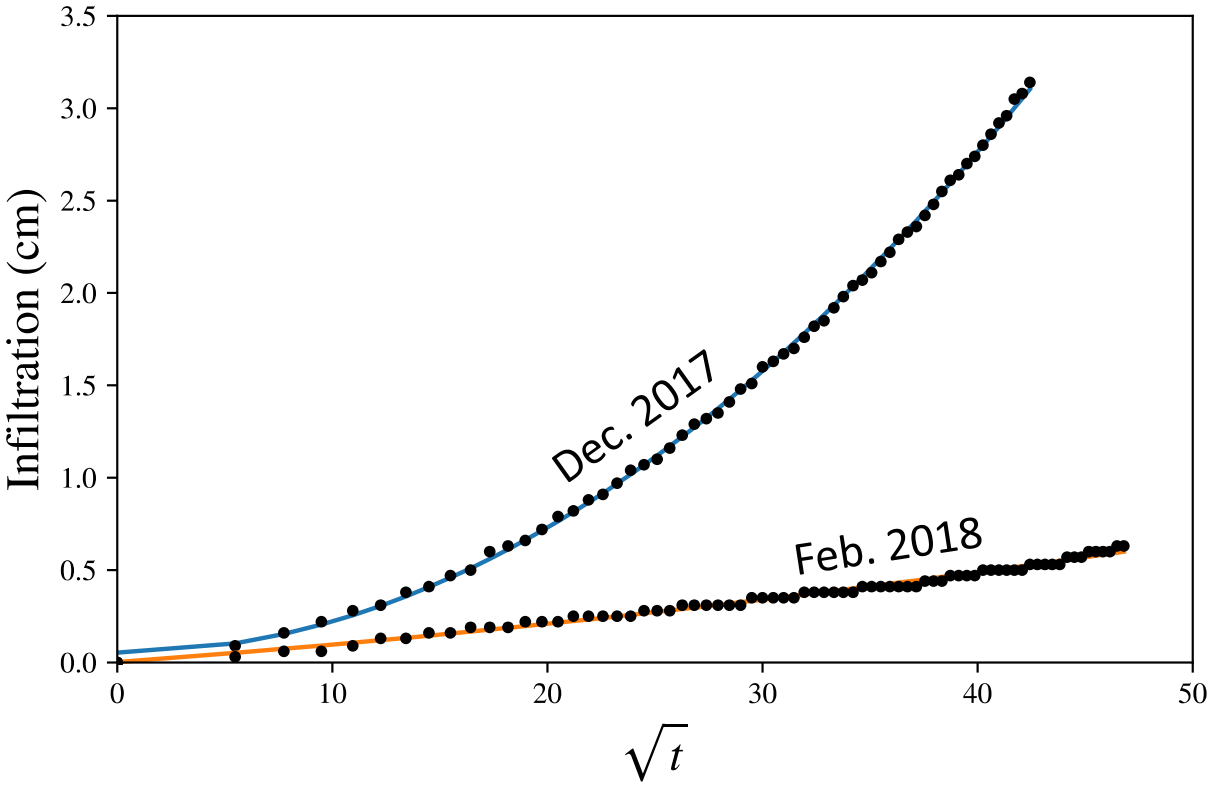
Size = burn severity

Potential soil sealing after 2017/2018 rainy season

How do soil macro-pores (cracking, etc) impact recovery?



Site PMD01 (Franciscan mélange grassland) changes over time



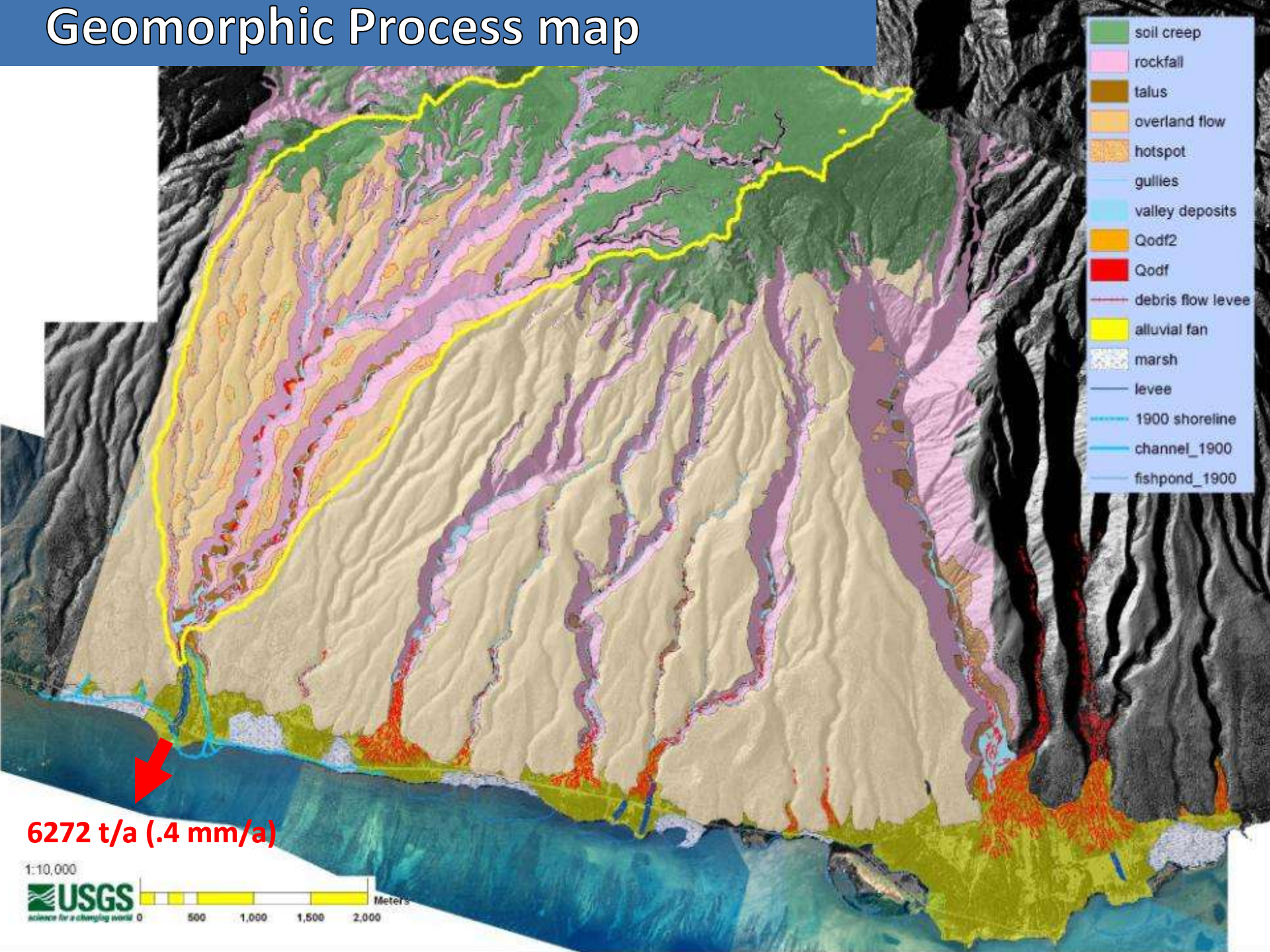
Objective 2: *Geomorphic process mapping*

*Goal: G*eomorphic process map for subset of burned watersheds to detect change over seasons

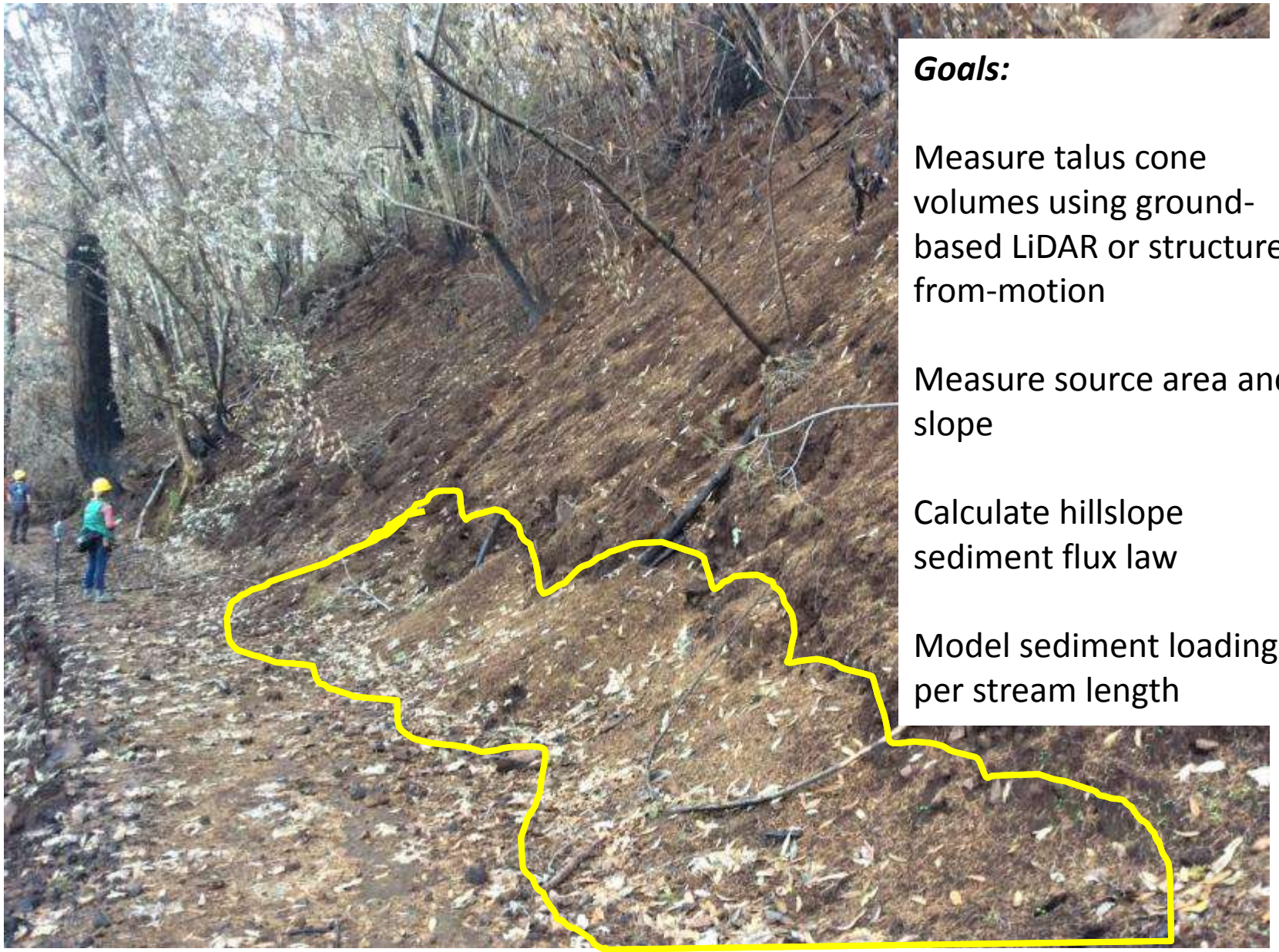
Utilize:

- Monthly (Digital Globe, sub-m-resolution) and daily (Planet labs smallsats, ~6 m resolution) satellite imagery
- Pre- and (hopefully) post-fire Lidar
- Correlate Pit2Pixel measurements to extrapolate over greater areas

Geomorphic Process map



Calculating hillslope sediment flux and stream loading



Goals:

Measure talus cone volumes using ground-based LiDAR or structure-from-motion

Measure source area and slope

Calculate hillslope sediment flux law

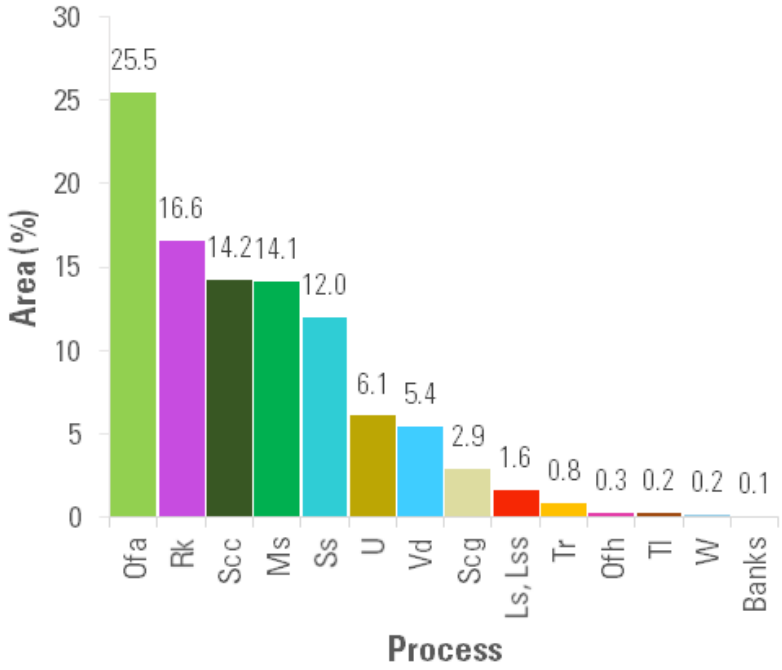
Model sediment loading per stream length

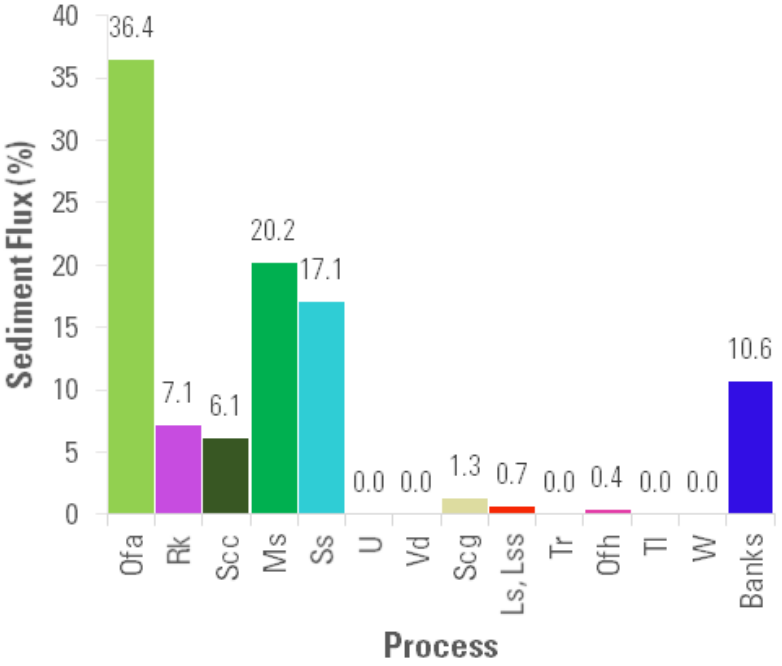
Bouverie Preserve, Glen Ellen, CA

Modeling

- Calculate sediment flux: erosion rate x process area

Ls	Landslide
Lss	Landslide Scarp
Ms	Modified Soil
Ofa	Agricultural Field
Ofh	Hot Spots
Rk	Rockfall
Scc	Soil Creep, canopy
Scg	Soil Creep, grass
Ss	Side Slope
Tl	Talus
Tr	Terrace
U	Urban
Vd	Valley Deposit
W	Waterways





What will be the net effect on fuel loads and risk of future fire? Flood risks? Drought resilience?

Can we inform *extreme event*-smart strategies for rebuilding our community?

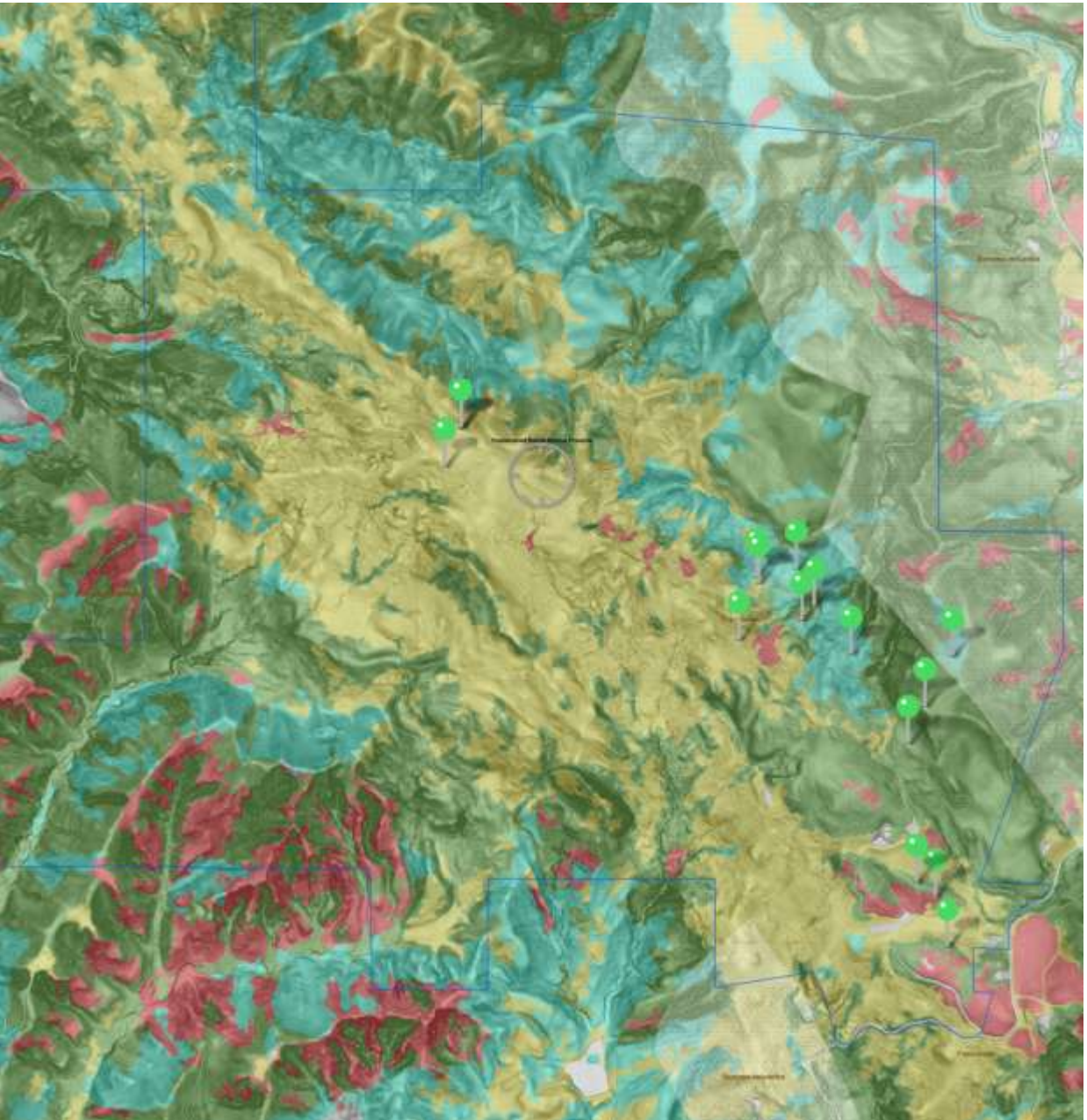
Help us fill knowledge gaps!

1. Fractured bedrock hillslope hydrology: storage, springs
2. Residence times, landscape memory, fog inputs
2. Relationships between soil carbon and moisture holding capacity, stream flow onset and duration
3. Can we develop small catchment indicators as a surrogate for distributed sampling of soil characteristics?
4. Fire recovery of soils, infiltration and erosion rates? How are Coast Range watersheds different?
5. How effective were fuel treatments in mitigating fire severity and in turn watershed impacts?
6. How can we assess hydrologic impacts of long-term vegetation mgt in a multi-benefit context?

Thank you!

lmicheli@pepperwoodpreserve.org

Pepperwood Preserve

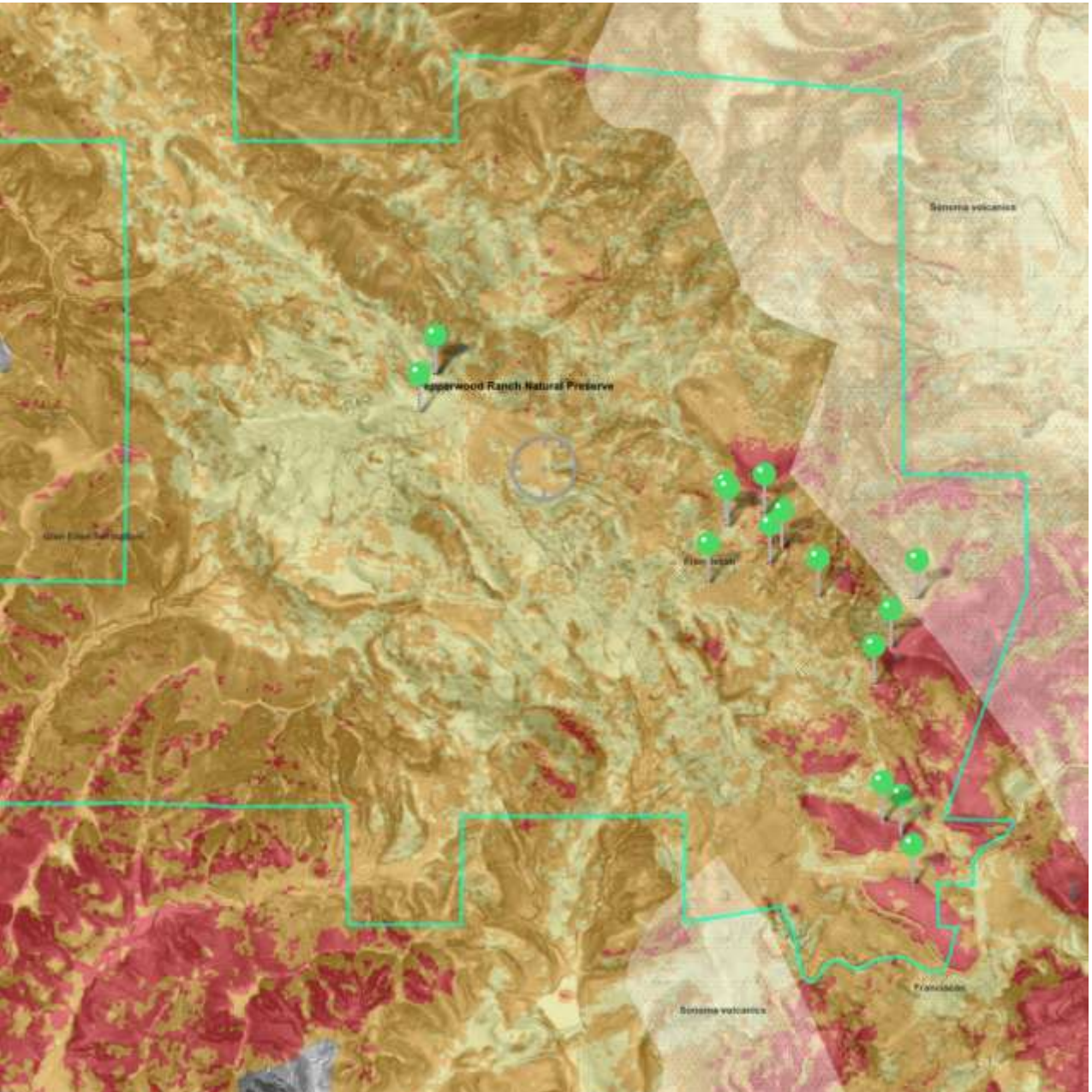


Highest burn severity to south of Preserve

15 monitoring sites across a range of vegetation and geology types

Additional ~34 grassland sites that have been monitored since 2015

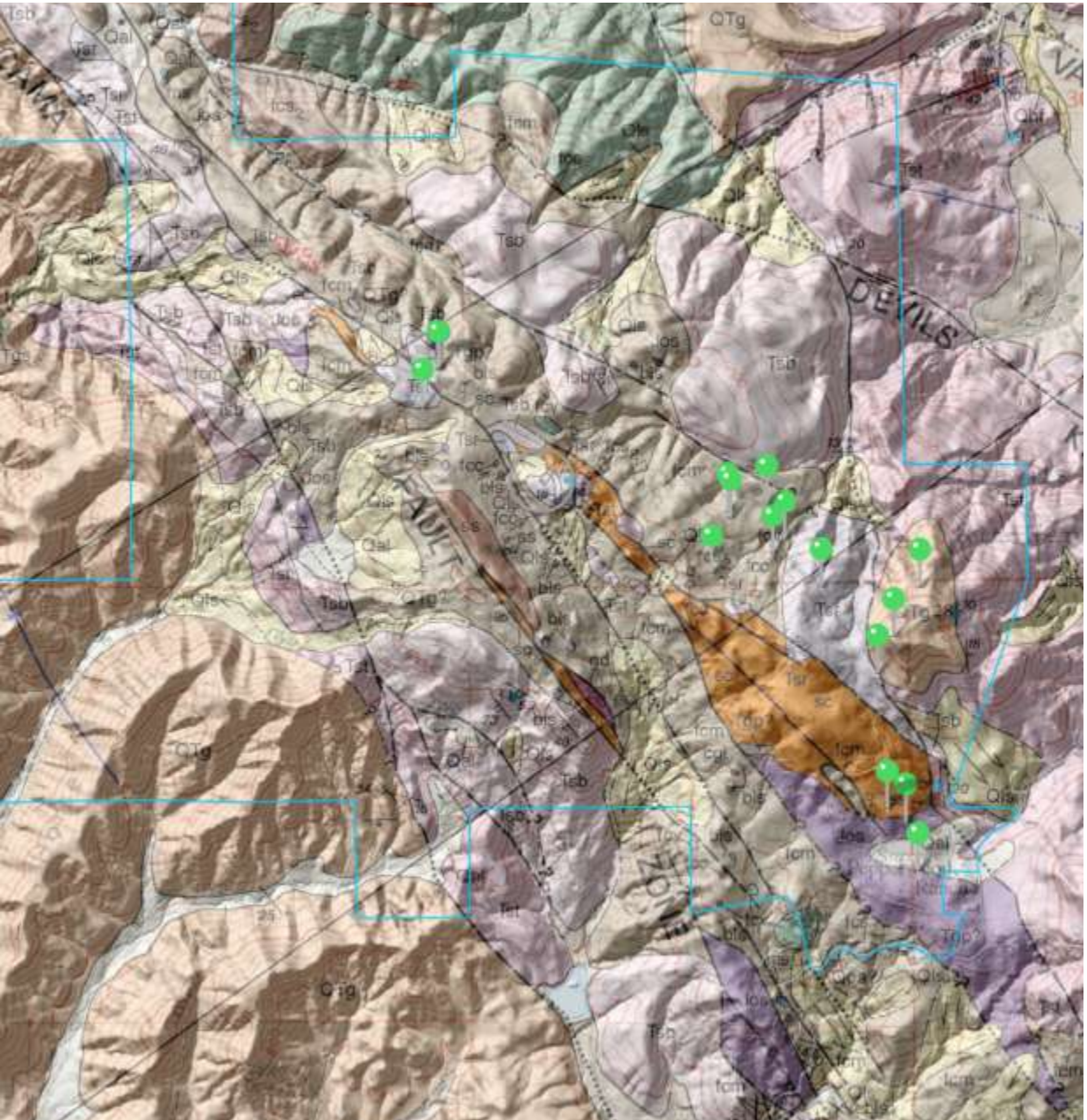
Pepperwood Preserve



Highest burn severity to south of Preserve


SMD Jos Chaparral
SMD Fc Manzanita
SMD Fc Madrone Bay Live Oak
SMD Evergreen
SMD Mod Sbs Chap
Image Landsat / Copernicus
Google Earth
Tour Guide
1993
Imagery Date: 10/17/2017 lat 38.512718° lon -122.539460° elev 671 m eye alt 2.94 km

Pepperwood Preserve



Highest burn severity to south of Preserve

15 monitoring sites across a range of vegetation and geology types